Long-Term Follow-Up of the Residents of the Three Mile Island Accident Area: 1979–1998

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The Three Mile Island (TMI) nuclear power plant accident (1979) prompted the Pennsylvania Department of Health to initiate a cohort mortality study in the TMI accident area. This study is significant because of the long follow-up (1979–1998), large cohort size (32,135), and evidence from earlier reports indicating increased cancer risks. Standardized mortality ratios (SMRs) were calculated to assess the mortality experience of the cohort compared with a local population. Relative risk (RR) regression modeling was performed to assess cause-specific mortality associated with radiation-related exposure variables after adjustment for individual smoking and lifestyle factors. Overall cancer mortality in this cohort was similar to the local population [SMRs = 103.7 (male); 99.8 (female)]. RR modeling showed neither maximum gamma nor likely gamma exposure was a significant predictor of all malignant neoplasms; bronchus, trachea, and lung; or heart disease mortality after adjusting for known confounders. The RR estimates for maximum gamma exposure (≤ 8, 8–19, 20–34, ≥ 35 mrem) in relation to all lymphatic and hematopoietic tissue (LHT) are significantly elevated (RRs = 1.00, 1.16, 2.54, 2.45, respectively) for males and are suggestive of a potential dose–response relationship, although the test for trend was not significant. An upward trend of RRs and SMRs for levels of maximum gamma exposure in relation to breast cancer in females (RRs = 1.00, 1.08, 1.13, 1.31; SMRs = 104.2, 113.2, 117.9) was also noted. Although the surveillance within the TMI cohort provides no consistent evidence that radioactivity released during the nuclear accident has had a significant impact on the overall mortality experience of these residents, several elevations persist, and certain potential dose–response relationships cannot be definitively excluded. *Key words:* **dose–response relationship, epidemiology, ionizing radiation, mortality, neoplasms, nuclear reactors.** *Environ Health Perspect* **111:341–348 (2003). doi:10.1289/ehp.5662 available via** *http://dx.doi.org/* **[Online 30 October 2002]**

On 28 March 1979, an accident at Three Mile Island (TMI) nuclear power plant in Pennsylvania produced the release of small quantities of xenon and iodine radioisotopes into the environment. Based on residential proximity and travel into and out of a 5-mile area during the 10 days after the accident, scientists estimated maximum and likely whole-body gamma exposures for each individual. The estimated average likely and maximum gamma doses were 0.09 mSv or 9 mrem and 0.25 mSv or 25 mrem, respectively. The range of likely gamma exposure was estimated to be 1–170 mrem. The average annual effective dose from natural background radiation in the United States is estimated to be approximately 3 mSv (300 mrem) [Committee on the Biological Effects of Ionizing Radiation (BEIR V) 1990]. These exposures were therefore considered minimal.

However, in the late 1970s and 1980s, several investigators reported an increased cancer risk, primarily leukemia, among persons exposed to fallout from nuclear weapons testing (BEIR V 1990). Estimates of the doses were reported to be sufficiently low so that "no detectable increase in risks would have been predicted on the basis of cancer risk estimates from high dose studies" (BEIR V 1990). A possible exception to this would be the dose to the thyroid in some individuals. These studies included residents of Utah and neighboring states downwind of the Nevada test site as well as veterans who participated in the test (Dalager et al. 2000; Rallison et al. 1990).

Because the long-term effects from exposure to low-dose exposure remain a concern, public health officials immediately began to assess whether the brief exposure to low-level radiation emitted from TMI would pose any health risks to the individuals residing near the facility. The Pennsylvania Department of Health (PADoH) created the TMI Population Registry, which was a compilation of individual sociodemographic, medical, occupational, and behavioral information. Over 93% of the population residing within the 5-mile radius of TMI was interviewed and included in this registry.

Four large-scale health end point studies have focused on residents living near the TMI facility. Two investigations (Hatch et al. 1991; Ramaswamy et al. 1991) focused on hospital- or registry-based cancer incidence among residents living within either 5 or 10 miles of the TMI nuclear plant and were carried out during a 6-year interval subsequent to the accident. The remaining two studies (Ramaswamy et al. 1989; Talbott et al. 2000a) assessed the mortality experiences of the residents living within 5 miles of the TMI facility with 6 and 13 years of follow-up, respectively.

In 1985, investigators at Columbia University (Hatch et al. 1991) initiated a study to ascertain cancer cases (based on hospital records) that occurred before and after the TMI accident. The cohort included individuals who resided within a 10-mile radius of the greater TMI area (1979–1985) and included nearly 160,000 persons. The study area was divided into 69 study tracts, and cancer cases within each tract were ascertained for the 1975–1985 period. Cancer rates were adjusted for population density, income, and education, but analyses were limited because no personal risk factor information was collected. For accident emissions, the researchers found no definite effects of exposure on the cancer types and population subgroups considered. No association was seen for leukemia in adults or for childhood cancers. However, elevated risks were noted for non-Hodgkin's lymphoma relative to accident emissions [odds ratio (OR) = 2.0; 95% confidence interval (CI), 1.2–3.5] as well as for lung cancer (OR = 1.75; 95% CI, 1.47–2.08). Background gamma radiation also showed a slight increase in risk for lung cancer with an OR of 1.1 (95% CI, 0.9–1.4).

In a reanalysis of the Columbia University study, Wing et al. (1997) considered Poisson regression models (for all cancers, lung cancers, and leukemia) to describe the relationship between cancer incidence and accident dose. Models were adjusted for age, sex, time period (preaccident, postaccident), and socioeconomic status. Wing et al. (1997) noted large percent increases in postaccident cancer rates per relative accident dose for all three sites considered (all cancer = 2%, lung cancer = 8.2%, and leukemia = 11.6%). Percent increases were

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